Experimental Design(c)

National Science Olympiad

May 16, 2015

How many M & M's fit in a package? How many jelly beans in a jar? Figuring out how many individual pieces will fit in a container is a food technology problem, an industrial design issue, or a fun carnival game. The aim is to understand packing fractions. One has to consider the shape of the container and the shape of the object.

The premise is to design an experiment manipulating packing fractions. (It would be helpful to make up a problem that you are trying to solve in your hypothesis.)

Packing fraction = volume of items/volume of the container

Equipment: Graduated cylinders (2), beakers (2), measuring cup, large pill container, fuji bottle, glass

Marbles, small and large, crayons small and large

ACCURATE

CONCISE

CREATIVE

MATHEMATICAL

READABLE

CLEAN UP!!!!

2015 Experimental Design Rubric for B/C (rev. 10/20/14)

(Note: all tasks listed under each section are worth a maximum of 2 points unless otherwise stated)

a. Statement of problem (4 Points)
_____ Not a yes/no question and includes independent and dependent variables
_____ Problem is clearly testable and is written in a clear and concise manner

b. Hypothesis (8 points)
_____ Statement predicts a relationship or trend
_____ Statement gives specific direction to the predictions(s): A stand is taken.
_____ Prediction includes both independent and dependent variables
_____ A rationale is given for the hypothesis.

c. Variables

Controlled Variables (CV) (8 points)
_____ One CV correctly identified
_____ Two CVs correctly identified
_____ Three CVs correctly identified
_____ Four CVs correctly identified

Independent Variable (IV) (6 Points)
_____ IV correctly identified
_____ IV operationally defined
_____ At least three levels of IV given

Dependent Variable (DV) (6 points)
_____ (3pts) DV correctly identified
_____ (3pts) DV operationally defined

d. Experimental Control (Standard of Comparison-SOC) (4 points)
_____ SOC correctly identified and makes logical sense for the experiment
_____ Reason given for selection of SOC

e. Materials (6 points)
_____ All materials used are listed
_____ All materials used are listed properly (no extras)
_____Materials listed separately from procedure

f. Procedure: Including Diagrams (12 points)
_____ (2pts) Procedure well organized
_____ (2pts) Procedure is in a logical sequence
_____ (2pts) Diagrams used
_____ (2pts) Repeated trials
_____ (4pts) Enough information is given so another could repeat procedure

g. Qualitative Observations (8 points)
_____ Observations about results given
_____ Observations about procedure/deviations
_____ Observations about results not directly relating to Dependent Variable
_____ Observations given throughout the course of the experiment

h. Quantitative Data - Data Table (12 points)
_____ All raw data is given
_____ All data has units
_____ Condensed table with most important data included
_____ Table(s) labeled properly
_____ Example calculations are given
_____ All data reported using correct figures (significant figures C Division only)

i. Graphs (12 points)
_____ Appropriate type of graph used
_____ Graph has title
_____ Graph labeled properly (axes/series)
_____ Units included
_____ Appropriate scale used
_____ Drawn in line best of-fit

j. Statistics **Division B&C** (**6** points)
_____ Average (mean), median, mode, range, or other appropriate statistic used

k. Analysis and interpretation of data (8 points)
_____ All data discussed and interpreted
_____ Unusual data points commented on
_____ Trends in data explained and interpreted
_____ Enough detail is given to understand data and all statements must be supported by the data.

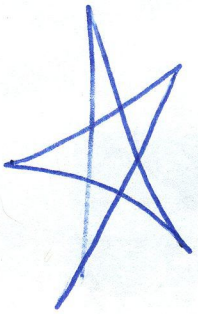
l. Possible Experimental Errors (6 points)
_____ Possible reasons for errors are given
_____ Important info about data collection given
_____ Effect errors had on data discussed

m. Conclusion (8 points)
_____ Hypothesis is evaluated according to data
_____ Hypothesis is re-stated
_____ Reasons to accept/reject hypothesis given
_____ All statements are supported by the data

n. Applications and Recommendations for Further Use (8 points)
_____ Suggestions for improvement of specific experiment are given
_____ Suggestion for other ways to look at hypothesis given
_____ Suggestions for future experiments given
_____ Practical application(s) of experiment given

C11 (1)

EXPERIMENTAL DESIGN



122/122 OK points

1. Statement of problem (4 points)

How can the packing fraction of crayons be maximized by using different sizes of crayons in order to make shipping more efficient?

2. Hypothesis (8 points)

If the size of crayons put in a package (IV) is increased, then the packing fraction (DV) will decrease. This is because the more cylindric shape of larger crayons requires more air space in between them to fit in the same area as smaller crayons are put in since the larger crayon's longer shape is less compact doesn't allow them to pack as closely together.

3. Variables

Independent variables (6 points)

The IV of the experiment is the size of the crayon, measured by its height. This will be measured in centimeters (cm).
IV level 1: 2cm IV level 2: 3cm IV level 3: 7cm

Dependent variables (6 points)

The DV of the experiment is the packing fraction. This will be measured by calculating the volume of all the objects and dividing it by the volume of the container. Both volume types are measured in milliliters (mL).

Constants (8 points)

- same circumferance of all crayons' faces/flat ends
- same height that crayons are filled up to in container
- same gradulated cylinder used to measure volume
- same shape of container crayons are "packed" in (32)

32

32

4. Standard of comparison (4 points)

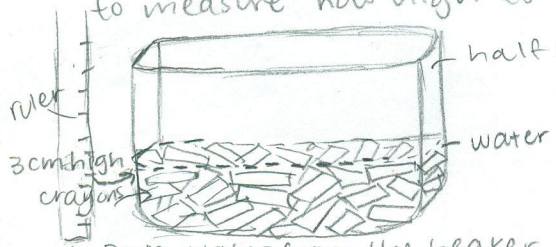
The SOC is the 2cm crayon because it is the lowest level of IV and is easy to compare to other levels.

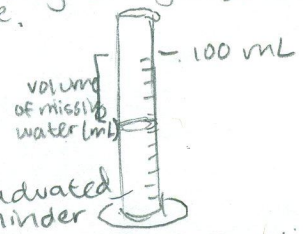
5. Materials (6 points)

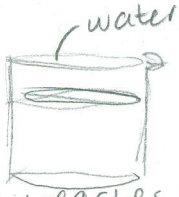
- 1 graduated cylinder (100 mL)
- Crayons (2cm long, 3cm long, 7 cm long; enough to fill Fiji bottle up to 3cm high (83 mL))
- 1 cm ruler
- 1 Fiji bottle (cut in half to make a cup)
- 1 beaker full of water
- 1 paper towel

6. Procedure(including diagrams) (12 points)

1. Sort crayons into three sizes - 2 cm long, 3 cm long, and 7 cm long.
2. Fill the Fiji bottle up to 3 cm high with water from the beaker, then pour that water into the graduated cylinder to measure the total volume that we are filling up to. (83 mL)
3. Start with the level of IV 2 cm crayons. First, fill the half of the Fiji bottle up to 3cm high with the 2 cm long crayons. Use the cm ruler to measure how high to fill the bottle.







4. Pour water from the beaker into the graduated cylinder until it reaches 100mL.
5. Pour water from the graduated cylinder into the Fiji bottle up to 3 cm, the height the crayons are filled up to.
6. Measure the volume of the missing water in the graduated cylinder by subtracting the volume of water in the cylinder from 100 mL (the total volume of the cylinder). Then subtract the volume of the missing water from the volume of the total volume in the bottle to find the volume of the crayons. To find the packing fraction, divide the volume of the crayons by the total volume (83 cm). Record packing fraction (DV).

7. Qualitative observations and results (8 points)

- observations about results: as the length of crayon increased, the packing fraction decreased.
- observations about procedure/deviations:
  - crayon lengths were not uniform, may have varied
  - crayons floated in water
  - it was hard to measure height b/c the Fiji bottle was weirdly shaped (base was round + rectangular)
- observations not directly related to DV:
  - crayons were different colors
  - graduated cylinder was 100 mL
  - crayons were waxy / floated in water
  - observations throughout experiment
  - crayons got more and more wet throughout experiment, may have absorbed water

FLIP OVER TO BACK FOR CONT. PROCEDU

(30)

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Procedure (cont.)

7. Pour water out of Fiji bottle back into water beaker. Pour crayons out and dry crayons with paper towel.
8. Repeat steps 3-7 two more times for a total of 3 trials for this level of IV.
9. Repeat steps ~~3~~8 two more times for the two other levels of IV, 3cm and 7cm long crayons. (Instead of using 2cm long crayons, substitute in 3cm or 7cm long crayons)
10. Clean up.

39
Total = 83

The effect of crayon length on packing fraction

8. Data table (12 points)

Packing fraction

Crayon length (cm)	Trial 1	Trial 2	Trial 3
2 cm	0.63	0.67	0.62
3 cm	0.53	0.51	0.57
7 cm	0.25	0.24	0.24

Packing fraction = $\frac{\text{total volume} - \text{volume of water}}{\text{total volume}}$

ex. $\frac{83mL - 39mL}{83mL} = 0.53$

The effect of crayon length on packing fraction (condensed)

Crayon length (cm)	Packing fraction (average)
2 cm	0.64
3 cm	0.54
7 cm	0.24

Average = $\frac{T_1 + T_2 + T_3}{3}$

ex. $\frac{0.63 + 0.67 + 0.62}{3} = 0.64$

12

Note: Packing fraction has no units because it is a ratio of two volumes.

9. Graph (12 points) attached graph paper

12

10. Statistics(6 points)

Packing fraction statistics

Crayon length (cm)	Mean	Median	Mode	Standard Deviation
2 cm	0.64	0.63	N/A	0.022
3 cm	0.54	0.53	N/A	0.025
7 cm	0.24	0.24	0.24	0.0047

Best fit line on graph paper

6

Sample calculations:

Mean = $\frac{T_1 + T_2 + T_3}{3}$

ex. $\frac{0.63 + 0.67 + 0.62}{3} = 0.64$

Median = middle value
ex. $0.62 < 0.63 < 0.67$, so median = 0.63

Mode = most common value

Standard deviation = $\sqrt{\frac{\Sigma(x - \bar{x})^2}{n}}$

ex. $\sqrt{\frac{(.62-.63)^2 + (.63-.63)^2 + (.62-.63)^2}{3}}$

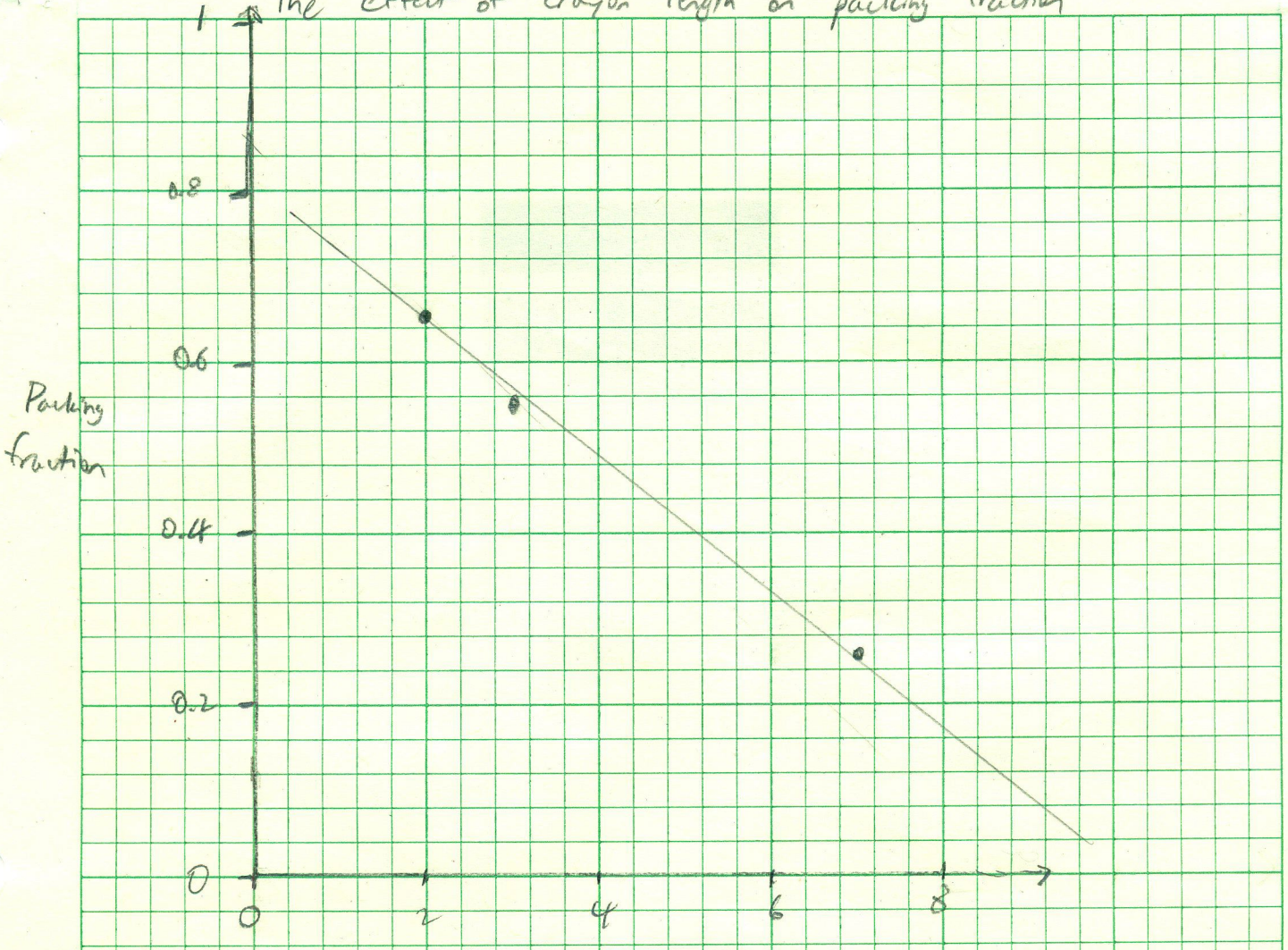
$= 0.022$

11. Analysis of results /interpretation (8 points)

- The data demonstrated that as crayon length increased, packing fraction decreased, so crayon length seems to be inversely correlated to packing fraction
- For all our IV levels, the standard deviation was fairly small, so our data points for each IV were close to each other.
- There were no outliers.
- At crayon length of 2 cm, the average packing fraction was 0.64.
- When this was increased to 3 cm, average packing fraction decreased to 0.54, and at 7 cm, it further decreased to 0.24. Therefore, packing fraction is inversely correlated with crayon length.

8

The effect of crayon length on packing fraction



Best fit line:

$y = 0.786x + 0.7876$

12. Possible experimental errors(6 points)

Random • The label could have shaken while pouring water into the container causing the person to think they have filled up the container all the way since the water bumped up, when they actually haven't. this would increase the packing fraction as it would make it seem like less water is needed to fill up the spaces between the crayons in the container. (6)

Human • The person measured the amount of water to pour into the container could have mismeasured the amount of water by pouring water into the container so it fills a bit below the size of the container. This would increase the DV since less water would be measured as space between the crayons.

Material • There could have been bubbles in the water from pouring the water in too quickly. This would cause the DV to increase since the bubbles would take up more space allowing for less water to fit into the container making it seem like the crayons also take up the space where the bubbles are.
• some crayons could be larger than others, giving an imprecise measurement of volume of the crayons since the IV of the experiment assumes they are all uniform in size as listed. some larger crayons would decrease the DV while some smaller crayons would increase the packing fraction because larger crayons are not able to be packed as closely together as smaller crayons since their size is less compact.

13. Conclusion (8 points)

our hypothesis was if the size of the crayons put in a package increases, then the packing fraction will decrease. This can be supported by the data since it reflected the same inverse relationship between the IV and DV expressed in the hypothesis. the average decrease in packing fraction from IV level 1 to IV level 2 was 0.10 and the average decrease in packing fraction from IV level 2 to IV level 3 was 0.30. This is an overall decrease of 0.40. The overall decrease of packing fraction as the size of crayons increases supports the hypothesis. (8)

14. Recommendations for further experimentation based on data and practical applications(8)

improvement on specific experiment: draw a line on the container to know exactly how big the container you are using is so you don't accidentally put less or more water in.

improvement on hypothesis: we could use three different sized marbles to do the same experiment. (8)

improvement for future experiment: if the size of a container (IV) increases, then the packing fraction (DV) with same size and amount of crayons decreases.

(22)

Applications

- used when packing crayons for art classes
- used when packing foods in containers
- used when packing items for moving houses